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Probabilistic assessment of main factors determining the road traffic accident rate in regions of Russia

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Abstract

This paper sets forth the findings of the research on the traffic accident rate in the constituent entities of the Russian Federation, based upon respective regional statistical data for the four-year period from 2015 to 2018. In order to achieve the goal of the research — to identify the main factors affecting the accident rate, — the methods of correlation and regression analysis were used. We obtained regression equations relating the main indicators of the accident rate to the most relevant factors. The quality of the regression equations is characterized by means of the coefficients of correlation between actual and estimated values of the number of RTAs (road traffic accidents), the number of RTA fatalities and injuries. We assessed the role of each factor under consideration by means of confidence estimates and confidence probabilities, and determined factors that have both a positive and a negative influence on the accident rate.

Keywords: traffic accident rate; statistical analysis of data; mathematical modeling; factors; probabilistic assessment.

1. Introduction

In most countries of the world, ensuring road traffic safety is one of the high-priority problems. The Russian Federation is no exception — in recent years, the issues of ensuring road traffic and environmental safety have been addressed by such researchers as Brylev et al. (2018), Danilov et al (2018, 2020), Evtiukov et al. (2018a, 2018b), Ginzburg et al. (2017), Kerimov et al. (2017), Kurakina et al. (2018), Marusin (2017a, 2017b), Marusin and Abliazov (2019), Marusin et al. (2018, 2019, 2020), Podoprigora et al. (2017, 2018), Pushkarev et al. (2018), Repin et al. (2018), Safiullin et al. (2016, 2018, 2019), Skorokhodov et al. (2018), Soo et al. (2020), Vorozheikin et al. (2019). In order to address the issues of ensuring road traffic safety, the a posteriori approach has often been used. In the meantime, the

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scientific and technical progress created prerequisites for the automated generation and processing of data characterizing various facets of public activities, in particular, those concerning the road traffic. Moreover, it became possible to develop models based on such data, in order to select corresponding measures and take scientifically substantiated managerial decisions.

2. Theoretical studies

This paper is a continuation of the series of studies, performed in the Moscow Automobile and Road Construction State Technical University (MADI), on modeling the traffic accident rate in Russian regions.

As for these regions, a functional relationship between the population size $\overline{x}_1$ (thous. people), the number of vehicles (V) $\overline{x}_2$ (thous. units) and the key indicator of the accident rate — the "number of RTA (road traffic accident) fatalities" y — measured in units, by means of the regression analysis of data for 2015–2018 can be represented as follows (Silyanov 2020):

$$y = 0.380429 \cdot \overline{x}_1^{0.604845} \cdot \overline{x}_2^{0.302422} \quad (1)$$

This functional relationship can be viewed as the first approximation to the traffic accident rate model (the coefficient of rank correlation between the actual and estimated data is 0.921).

To improve the quality of the model, it is necessary to select factors associated with a set of numerically measured indicators characterizing drivers (individuals) as road users, cars (vehicles), roads and the environment, provided that the factors have a close correlative relationship with the number of RTA fatalities.

3. Calculations

For this purpose, we formed an array of data for 2015–2018 to characterize social and economic as well as natural and climatic conditions of 82 regions (with the required information available), and selected factors corresponding to the Spearman's rank correlation coefficient exceeding the threshold value at the level of significance equal to 0.05 (for the data array with a dimension of 328, this threshold value is equal to 0.1095) (Silyanov 2020).

The said list of factors includes natural conditions (measured in points), (x_9) (Geoteka 2020), the average annual temperature in the capital cities of the constituent entities of the Russian Federation (°C), (x_{10}) (Gosstroy of Russia 2000), the density of the federal, regional, inter-municipal and local public hard-surface roads by the constituent entities of the Russian Federation (km per 1000 km^2 of the territory), (x_{11}) (Autostat 2019, Federal State Statistics Service 2020), the investment potential of the Russian regions (share in the all-Russian potential, %), (x_1) (Expert 2020) the investment risk of the Russian regions, (x_3) (Expert 2020) the socio-economic status (x_5) (Prime 2013), the final assessment of life quality (rating score) (x_4) (GIBDD 2019), the number of initiated administrative offense cases related to road traffic (thous.) (x_7) [8], the number of administrative offenses registered by means of traffic cameras (thous.) (Fuelbroker 2019), the average age of the vehicle fleet (years) (x_{13}) (Trezvos 2019), the annual sales volume of gasoline in the regions (x_6) (Dubrov et al. 2011), the sobriety rating of the regions (x_2) (Aivazyan 1989).

Since equation (1) makes it possible to estimate the number of RTA fatalities well enough, it is reasonable to assume that "on average" this number might be made more accurate by complementing equation (1) in a linear manner with the factors from the compiled list that are characterized by significant values of the correlation coefficient. This means that the mathematical expectation Y of the number of RTA fatalities can be represented as follows:

$$Y = \alpha \cdot y + \sum_{i=1}^{n} a_i \cdot x_i + a_0 \qquad (2)$$

where $\alpha, a_0, a_i (i = 1,...,n)$ — parameters;

n — the number of factors;

x_i — the factors of the process under consideration ($i = 1,...,n$).

Taking into account equation (2) for each of 328 process implementations, it is possible to represent the estimate of the number of fatalities as follows:

$$Y_k = \alpha \cdot y_k + \sum_{i=1}^{n} a_i \cdot x_i^k + a_0 + \delta_k, \qquad (3)$$

where k — the seq. No. of the process implementation (k = 1, ..., 328);

δ_k — the estimation error determined by e.g. the presence of the unaccounted factors in the model.

The values of the unknown parameters in equation (3) can be determined using the least-squares method by way of minimizing the sum of squared deviations of the actual and estimated values Y_k (Aivazyan 1989):

$$\overline{Y}_k = \overline{\alpha} \cdot y_k + \sum_{i=1}^{n} \overline{a}_i \cdot x_i^k + \overline{a}_0,$$

(k = 1, ..., 328),

where $\overline{a}_0, \overline{a}_i, \overline{\alpha}$ — estimates of the equation parameters by the least-squares method (3) a_0, a_i, α .

To build the model, the factors are broken down into three groups — socio-economic, administrative, and others. We used an algorithm of building the main components described in the paper (Kapitanov et al. 2017, 2020).

As to the list of socio-economic indicators, the main components look as follows (Kapitanov et al. 2017, 2020, Silyanov 2020):

$$\begin{aligned} y_1^1 &= -0.442 \cdot x_3 + 0.501 \cdot x_4 + 0.403 \cdot x_1 + 0.504 \cdot x_5 + 0.371 \cdot x_6 \\ y_2^1 &= 0.568 \cdot x_3 - 0.234 \cdot x_4 + 0.531 \cdot x_1 - 0.116 \cdot x_5 + 0.573 \cdot x_6 \\ y_3^1 &= 0.228 \cdot x_3 + 0.118 \cdot x_4 + 0.622 \cdot x_1 + 0.121 \cdot x_5 - 0.729 \cdot x_6 \\ y_4^1 &= 0.530 \cdot x_3 + 0.015 \cdot x_4 - 0.370 \cdot x_1 + 0.762 \cdot x_5 - 0.022 \cdot x_6 \\ y_5^1 &= 0.387 \cdot x_3 + 0.825 \cdot x_4 - 0.177 \cdot x_1 - 0.370 \cdot x_5 + 0.042 \cdot x_6 \end{aligned} \qquad (4)$$

The relative fractions of the total variance, determined by one, two, three, four or five main components, are equal to 0.677, 0.826, 0.935, 0.970, 1.0, respectively. Acceptable accuracy is achieved by the three first components, which are used below.

By means of the method of the main components and equation (1), the following regression equation can be obtained for the regions to connect the average number of fatalities Y_k (3) with the above-mentioned factors (subscript k is omitted):

$$\overline{Y}_k = 1.36655647 \cdot y - 2.724867 \cdot x_9 + 3.56146 \cdot x_{10} + 1.1811 \cdot x_2 - 0.00611 \cdot x_{11} - 0.511728 \cdot x_{13} + 14.132926 \cdot y_1^1 - 26.958 \cdot y_2^1 - 102.00 \cdot y_3^1 - 0.0157526 \cdot x_7 + 12.2969696 \qquad (5)$$

This equation describes the process on average. The difference between the estimated and actual values (in the case under consideration, it is the number of RTA fatalities) is suggested to be associated with the random nature of values Y_k, a_i, a_0, δ_k, included in equation (3).

In order to account for the said randomness, we can use necessary theoretical provisions, presented, for example, in the paper on mathematical statistics (Aivazyan 1989). Random values δ_k are considered independent and identically distributed random variables with zero mathematical expectation.

Estimates of confidence intervals, based on these provisions, for the coefficients of the factors in equation (3), with account for (5), are presented in Table 1.

The position on the numerical axis of the interval (min, max), corresponding to a particular confidence probability, characterizes the influence of the factor on the indicator under consideration (with such probability). At min > 0 and max > 0, the factor adversely affects the accident rate, at min < 0 and max < 0, it has a positive influence, and at min < 0 and max > 0, its influence is uncertain.

Table 1. Variation range (from min to max) of the coefficients of the factors in equations (3), (5), corresponding to different values of confidence probability.

Factor		Confidence probability					
		0.95		0.9		0.6827	
		min	max	min	max	min	max
Population and transport, equation (1)		1.225071	1.508042	1.249828	1.483285	1.295812	1.437301
Natural environment		-38.71369	33.263964	-32.41649	26.966763	-20.71979	15.270060
Average annual air temperature		-1.320457	8.443384	-0.466235	7.589162	1.120434	6.002493
Sobriety rating (average in 4 years)		-0.897733	3.259990	-0.533981	2.896238	0.141668	2.220589
Density of motor roads		-0.102268	-0.019945	-0.095065	-0.027147	-0.081688	-0.040525
Average age of the vehicle fleet		-4.293810	5.317267	-3.452954	4.476410	-1.891110	2.914566
Socio-economic indicators (components)	y_1^1	7.861333	20.4045	8.958715	19.307138	10.997041	17.268812
	y_2^1	-44.63231	-9.283762	-41.53973	-12.37634	-35.7954	-18.120649
	y_3^1	-123.9187	-80.08199	-120.0835	-83.91719	-112.959	-91.040869
Number of registered administrative offenses		-0.025063	-0.006442	-0.023434	-0.008071	-0.020408	-0.011097

Factor		Confidence probability	
		0.8	
		min	max
Population and transport, equation (1)		1.276042	1.457070
Natural environment		-25.748442	20.298708
Average annual air temperature		0.438293	6.684634
Sobriety rating (average in 4 years)		-0.148807	2.511064
Density of motor roads		-0.087439	-0.034774
Average age of the vehicle fleet		-2.562578	3.586034
Socio-economic indicators (components)	y_1^1	10.120724	18.145129
	y_2^1	-38.265020	-15.651057
	y_3^1	-116.022476	-87.978259
Number of registered administrative offenses (thous.)		-0.021709	-0.009796

It follows from Table 1 that at the level of probability equal to at least 0.95, the increase in the number of fatalities is related to the population size and the number of vehicles in the entity, and the decrease in the number of fatalities is related to the density of roads (the higher the density, the less is the number of RTA fatalities), measures of administrative influence, and socio-economic situation in the region. The influence probability upward the sobriety rating is estimated approximately at 0.68. The same applies to the average annual temperature in the capital of the entity (probability is 0.8).

When the main components are replaced with factors (4), equation (5) will look as follows:

$$\overline{Y}_k = 1.36655647 \cdot y - 2.724867 \cdot x_9 + 3.56146 \cdot x_{10} + 1.1811 \cdot x_2 - 0.00611 \cdot x_{11} - 0.511728 \cdot x_{13} - 44.815 \cdot x_3 + 1.35273 \cdot x_4 - 72.06338 x_1 - 2.09192 \cdot x_5 + 64.15463 \cdot x_6 - 0.0157526 \cdot x_7 + 12.2969696$$

A similar approach is used in modeling the number of injured and the number of RTAs.

The regression equation for the estimation of the number of injured $y_r^{'}$ can be written in the following form:

$$y_r^{'} = 2.37267 \cdot x_1^{-0.645484} \cdot x_2^{-0.322742} + 351.1846 \cdot x_9 - 13.61246 \cdot x_{10} + 15.86418 \cdot x_2 - 0.0468388 \cdot x_{11} - 23.9325 \cdot x_{13} + 80.165768 \cdot y_1^1 - 24.26649 \cdot y_2^1 - 309.958456 \cdot y_3^1 - 0.1985895 \cdot x_7 - 1492.026 \quad (6)$$

Respective confidence estimates are given in Table 2.

Table 2. Variation range (from min to max) of the coefficients of the factors in equation (3), with account for (6), corresponding to different values of confidence probability (for the number of injured).

Factor		Confidence probability					
		0.8		0.9		0.95	
		min	max	min	max	min	max
Population and transport		0.821405	0.927384	0.806328	0.94246	0.793214	0.955575
Natural environment		192.694981	509.67427	147.602622	554.766626	108.37696	593.99228
Average annual air temperature		-35.309094	8.08417	-41.482067	14.257144	-46.851912	19.626988
Sobriety rating		6.671774	25.056595	4.056414	27.671955	1.781323	29.947046
Density of motor roads		-0.22871	0.13504	-0.28046	0.18678	-0.32547	0.23180
Average age of the vehicle fleet		-45.193694	-2.67138	-51.242769	3.377698	-56.504836	8.639764
Socio-economic indicators (components)	y_1^1	52.471776	107.8598	-51.242769	3.377698	-56.504836	8.639764
	y_2^1	-103.546849	55.01386	-126.103138	77.57015	-145.724764	97.19178
	y_3^1	-407.81	-212.106	-435.651	-184.266	-459.869	-160.048
Number of registered administrative offenses (thous.)		-0.23994	-0.15724	-0.25171	-0.14547	-0.26194	-0.13524

Factor	Confidence probability			
	0.75		0.7	
	min	max	min	max
Average annual air temperature	-33.08184	5.856916	-31.150389	3.925465
Density of motor roads	-0.21004	0.11637	-0.19385	0.10018

It should be pointed out that as distinct from the factors affecting the number of RTA fatalities, the density of motor roads is not related to the number of injured, and the temperature rather contributes to the reduction in the number of injured (with a significant shift of the lower boundary of the interval to the negative side). The natural environment, as well as the sobriety rating with a probability of at least 0.95 increase this value.

When the main components are replaced with factors (4), equation (6) will look as follows:

$$y_r^{'} = 2.37267 \cdot x_1^{-0.645484} \cdot x_2^{-0.322742} + 351.1846 \cdot x_9 - 13.61246 \cdot x_{10} + 15.86418 \cdot x_2 - 0.0468388 \cdot x_{11} - 23.9325 \cdot x_{13}$$
$$- 119.88717 \cdot x_3 + 9.26631 \cdot x_4 - 173.37286 \cdot x_1 + 5.71349 \cdot x_5 + 241.79651 \cdot x_6 - 0.1985895 \cdot x_7 - 1492.026 \quad (7)$$

The regression equation for the number of RTAs $y_v^{'}$ can be written in the following form

$$y_v^{'} = 1.90637 \cdot x_1^{-0.645086} \cdot x_2^{-0.322543} \cdot y_1^r + 265.83 \cdot x_9 - 5.6 \cdot x_{10} + 17.9198 \cdot x_2 + 0.088243 \cdot x_{11}$$
$$- 7.2467298 \cdot x_{13} + 60.3788 \cdot y_1^1 + 7.6652886 \cdot y_2^1 - 194.91565867 \cdot y_3^1 - 0.15242 \cdot x_7 - 1595.0364 \quad (8)$$

Respective confidence estimates are given in Table 3.

Table 3. Variation range (from min to max) of the coefficients of the factors in equation (3), with account for (7), corresponding to different values of confidence probability (for the number of RTAs).

Factor		Confidence probability					
		0.8		0.9		0.95	
		min	max	min	max	min	max
Population and transport		0.817306	0.981863	0.793897	1.005272	0.773533	1.025635
Natural environment		74.579224	457.083733	20.165479	511.497479	-27.168821	558.831779
Average annual air temperature		-31.778858	28.028397	-39.227246	28.028397	-45.706569	34.507721
Sobriety rating		6.827592	29.01203	3.671712	32.16791	0.926424	34.9132
Density of motor roads		-0.13122	0.30771	-0.19366	0.37015	-0.24798	0.42447
Average age of the vehicle fleet		-32.901882	18.40842	-40.201106	25.70765	-46.550671	32.05721
Socio-economic indicators (components)	y_1^1	26.960696	93.79693	17.452808	103.3048	9.181935	111.5757
	y_2^1	-87.9865	103.3171	-115.201	130.5313	-153.786	154.2048
	y_3^1	-312.979	-76.8518	-346.57	-43.2611	-375.791	-14.0407
Number of registered administrative offenses (thous.)		-0.20232	-0.10253	-0.21652	-0.08833	-0.22887	-0.07598

Factor	Confidence probability			
	0.75		0.7	
	min	max	min	max
Average annual air temperature	-29.091425	17.892576	-26.760911	15.562062

The density of roads, the average annual air temperature, the average age of the vehicle fleet are not related to the number of RTAs in terms of its increase or decrease, while the natural environment with a probability of at least 0.9 increases this value. The population size and the number of vehicles in the region, just like the sobriety rating, in 95% of cases contribute to the increase in the number of RTAs.

When the main components are replaced with factors (4), equation (7) will look as follows:

$$y_v^{'} = 1.90637 \cdot x_1^{-0.645086} \cdot x_2^{-0.322543} \cdot y_1^r + 265.83 \cdot x_9 - 5.6 \cdot x_{10} + 17.9198 \cdot x_2 + 0.088243 \cdot x_{11} - 7.2467298 \cdot x_{13}$$
$$- 66.77432 \cdot x_3 + 5.45606 \cdot x_4 - 92.83461 \cdot x_1 + 5.95695 \cdot x_5 + 168.88627 \cdot x_6 - 0.15242 \cdot x_7 - 1595.0364$$

It should be noted that coefficients of correlation between the actual and estimated values (equations (5)-(6)) of the number of fatalities, the number of injured as well as the number of RTAs are equal to 0.908, 0.952, 0.958, respectively, which is indicative of a sufficiently good model approximation of actual data. The factors that characterize the socio-economic status of the regions affect the accident rate indicators in different ways (upward or downward). No influence of the vehicles' age on the accident rate has been found.

4. Conclusions

The research resulted in obtaining the regression equations for the accident rate indicators and identified factors associated with them. The quality of the regression equations is assessed by sufficiently large values of the coefficients of correlation between the actual and estimated values (exceeding 0.9). The conclusions on the influence of the factors on the accident rate were evaluated by means of confidence intervals and confidence probabilities for the coefficients of the regression equation. We managed to prove the important role of the socio-economic status in the development of the process under consideration.

The results presented above testify to the possibility of using mathematical models of the road traffic accident rate in the development of proposals and selection of measures for its reduction.

References

Aivazyan, S.A., 1989. Applied statistics. Classification and reduction of dimensionality. Finansy i Statistika, Moscow.

Autostat, 2019. Average age of vehicle fleets in Russian regions. Available at: https://www.autostat.ru (accessed August 15, 2019).

Brylev, I., Evtiukov, S., Evtiukov, S., 2018. Problems of calculating the speed of two-wheeled motor vehicles in an accident. Transportation Research Procedia 36, 84–89. DOI: 10.1016/j.trpro.2018.12.047.

Danilov, I.K., Marusin, A.V., Marusin, A.V., Danilov, S.I., Andryushchenko, I.S., 2018. Diagnosis of the fuel equipment of diesel engines with multicylinder high pressure fuel injection pump for the movement of the injector valve for the diagnostic device. ICFET'18: Proceedings of the 4th International Conference on Frontiers of Educational Technologies, 157–160. DOI: 10.1145/3233347.3233363.

Danilov, I., Marusin, A., Mikhlik, M., Uspensky, I., 2020. Development of the mathematical model of fuel equipment and justification for diagnosing diesel engines by injector needle displacement. Transport Problems 15 (1), 93–104. DOI: 10.21307/tp-2020-009.

Dubrov, A.M., Mkhitaryan, V.S., Troshin, L.I., 2011. Multidimensional statistical methods. Finansy i Statistika, Moscow.

Evtiukov, S., Golov, E., Ginzburg, G., 2018a. Finite element method for reconstruction of road traffic accidents. Transportation Research Procedia 36, 157–165. DOI: 10.1016/j.trpro.2018.12.058.

Evtiukov, S., Karelina, M., Terentyev, A., 2018b. A method for multi-criteria evaluation of the complex safety characteristic of a road vehicle. Transportation Research Procedia 36, 149–156. DOI: 10.1016/j.trpro.2018.12.057.

Expert, 2020. Investment climate of regions — 2014. Available at: https://raexpert.ru/rankingtable/region_climat/.https://raexpert.ru/rankingtable/region_climat/2014/tab03 (accessed February 21, 2020).

Federal State Statistics Service, 2020. Unified Inter-departmental Statistical Information System (EMISS). Available at: http://www.gks.ru (accessed February 14, 2020).

Fuelbroker, 2019. Market of petroleum products and natural gas in Russia. Results of 2015. Available at: http://www.fuelbroker.ru/upload/iblock/f58/Годовой%20отчет%202015.pdf (accessed July 25, 2019).

Geoteka, 2020. Classification of Russian regions in terms of their natural environment. Available at: http://www.geoteka.ru/text.html?ident=usl.http://www.geoteka.ru/text.html?ident=usl (accessed March 23, 2020).

GIBDD, 2019. Statistical data of the state traffic police. Available at: http://www.gibdd.ru (date of information retrieval: July 28, 2019).

Ginzburg, G., Evtiukov, S., Brylev, I., Volkov, S., 2017. Reconstruction of road accidents based on braking parameters of category L3 vehicles. Transportation Research Procedia 20, 212–218. DOI: 10.1016/j.trpro.2017.01.054.

Gosstroy of Russia, 2000. Construction Rules and Regulations SNiP 23-01-99. Building climatology. Gosstroy of Russia, Moscow.

Kapitanov, V.T., Silyanov, V.V., Monina, O.Yu., Chubukov, A.B., 2020. Evaluation of the impact of anti-alcohol policy in the regions of the Russian Federation on road traffic accidents. IOP Conference Series: Materials Science and Engineering 832, 012046. DOI: 10.1088/1757-899X/832/1/012046.

Kapitanov, V., Silyanov, V., Monina, O., Chubukov, A., Brannolte, U., 2017. Simulation of regional mortality rate in road accidents. Transportation Research Procedia 20, 112–124. DOI: 10.1016/j.trpro.2017.01.031.

Kerimov, M., Safiullin, R., Marusin, A., Marusin, A., 2017. Evaluation of functional efficiency of automated traffic enforcement systems. Transportation Research Procedia 20, 288–294. DOI: 10.1016/j.trpro.2017.01.025.

Kurakina, E., Evtiukov, S., Rajczyk, J., 2018. Forecasting of road accident in the DVRE system. Transportation Research Procedia 36, 380–385. DOI: 10.1016/j.trpro.2018.12.111.

Marusin, A.V., 2017a. A method of assessing the efficiency of systems of automatic recording of traffic violations. PhD Thesis in Engineering. Saint Petersburg State University of Architecture and Civil Engineering, Saint Petersburg.

Marusin, A.V., 2017b. Improving the diagnostics of plunger pairs in high-pressure fuel pumps of motor and tractor diesel engines. PhD Thesis in Engineering. Kostychev Ryazan State Agrotechnological University, Ryazan.

Marusin, A.V., Abliazov, T.Kh., 2019. Public-private partnership as a mechanism for development of automated digital systems. Transport of the Russian Federation, 3 (82), 23–25

Marusin, A.V., Danilov, I.K., Khlopkov, S.V., Marusin, A.V., Uspenskiy, I.A., 2020. Development of a mathematical model of fuel equipment and the rationale for diagnosing diesel engines by moving the injector needle. IOP Conference Series: Earth and Environmental Science 422, 012126. DOI: 10.1088/1755-1315/422/1/012126.

Marusin, A., Marusin, A., Ablyazov, T., 2019. Transport infrastructure safety improvement based on digital technology implementation. Atlantis Highlights in Computer Sciences, Vol. 1. International Conference on Digital Transformation in Logistics and Infrastructure (ICDTLI 2019), 353–357. DOI: 10.2991/icdtli-19.2019.61.

Marusin, A., Marusin, A., Danilov, I., 2018. A method for assessing the influence of automated traffic enforcement system parameters on traffic safety. Transportation Research Procedia 36, 500–506. DOI: 10.1016/j.trpro.2018.12.136.

Podoprigora, N., Dobromirov, V., Pushkarev, A., Lozhkin, V., 2017. Methods of assessing the influence of operational factors on brake system efficiency in investigating traffic accidents. Transportation Research Procedia 20, 516–522. DOI: 10.1016/j.trpro.2017.01.084.

Podoprigora, N., Dobromirov, V., Stepina, P., 2018. Method of assessing the influence of the moisture content in the braking fluid on the braking system actuation efficiency. Transportation Research Procedia 36, 597–602. DOI: 10.1016/j.trpro.2018.12.147.

Prime, 2013. Where it is better to live in Russia: rating of regions in terms of quality of life. Available at: https://1prime.ru/ratings/20131217/773219432.html (accessed July 24, 2019).

Pushkarev, A., Podoprigora, N., Dobromirov, V., 2018. Methods of providing failure-free operation in transport infrastructure objects. Transportation Research Procedia 36, 634–639. DOI: 10.1016/j.trpro.2018.12.140.

Repin, S., Evtiukov, S., Maksimov, S., 2018. A method for quantitative assessment of vehicle reliability impact on road safety. Transportation Research Procedia 36, 661–668. DOI: 10.1016/j.trpro.2018.12.128.

Safiullin, R., Kerimov, M., Afanasyev, A., Marusin, A., 2018. A model for justification of the number of traffic enforcement facilities in the region. Transportation Research Procedia 36, 493–499. DOI: 10.1016/j.trpro.2018.12.135.

Safiullin, R.N., Kerimov, M.A., Marusin, A.V., 2016. Improving the efficiency of the system of photo and video fixation of administrative offences in road traffic. Bulletin of Civil Engineers 3 (56), 233–237.

Safiullin, R., Marusin, A., Safiullin, R., Ablyazov, T., 2019. Methodical approaches for creation of intelligent management information systems by means of energy resources of technical facilities. E3S Web of Conferences 140, 10008. DOI: 10.1051/e3sconf/201914010008.

Silyanov, V.V., 2020. Scientific basis for the formation of differentiated strategies to improve road traffic safety: R&D report (final). Moscow Automobile and Road Construction State Technical University (MADI), Moscow.

Skorokhodov, D., Seliverstov, Y., Seliverstov, S., Burov, I., Vydrina, E., Podoprigora, N., Shatalova, N., Chigur, V., Cheremisina, A., 2020. Using augmented reality technology to improve the quality of transport services. In: Sukhomlin, V., Zubareva, E. (eds). Convergent Cognitive Information Technologies. Convergent 2018. Communications in Computer and Information Science, 1140. Springer, Cham, 339–348. DOI: 10.1007/978-3-030-37436-5_30.

Soo, S., Abdel Sater, K.I., Khodyakov, A.A., Marusin, A.V., Danilov, I.K., Khlopkov, S.V., Andryushenko, I.S., 2020. The ways of effectiveness increase of liquid fuel with organic addition appliance in aerospace equipment. Advances in the Astronautical Sciences 170, 833–838.

Trezvos, 2019. National rating of sobriety of constituent entities of the Russian Federation – 2018. Available at: http://www.trezvros.ru/calendar/702 (accessed: August 15, 2019).

Vorozheikin, I., Marusin, A., Brylev, I., Vinogradova, V., 2019. Digital technologies and complexes for provision of vehicular traffic safety. Atlantis Highlights in Computer Sciences, Vol. 1. International Conference on Digital Transformation in Logistics and Infrastructure (ICDTLI 2019), 385–389. DOI: 10.2991/icdtli-19.2019.67.